Remarks

The foregoing amendments are being made to correct obvious typographical errors and do not comprise the introduction of any new matter, hence entry thereof is respectfully requested.

"Clean" and "Marked-Up" pages incorporating these amendments are included herewith.

Respectfully submitted,

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It is therefore an object of the present invention to provide a relatively low cost, low density product that is suited to application in the construction, aerospace, transportation, metal processing and other industries where such properties are desired.

It is another object of the present invention to provide a simple and low cost method for the production of such products.

Summary of the Invention

According to the present invention there are provided coal-based cellular or porous products, also referred to herein as "carbon foams", having a density of preferably between about 0.1 g/cm^3 and about 0.8 g/cm^3 and most preferably between about 0.3 and about 0.4 g/cm^3 that are produced by the controlled heating of coal particulate preferably up to ¼ inch in diameter in a "mold" and under a non-oxidizing atmosphere. According to a specifically preferred embodiment, the starting material coal has a free swell index as determined by aforementioned ASTM D720 test of between about 3.5 and about 5.0. According to further preferred embodiments of the present invention, the starting material coal exhibits one or more and preferably all of the following set of properties: 1) a volatile matter content (dry, ash-free basis) of between about 35 and about [35%] <u>45%</u> as defined by ASTM D3175, "Test Method for Volatile Matter in the Analysis of Coal and

2) a fixed carbon (dry basis) between about 50 and about 60% as defined by ASTM D3172, "Practice for Proximate Analysis of Coal and Coke"; 3) a Gieseler initial softening temperature of between about 380° C and about 400° C as determined by ASTM D2639, Test Method for Plastic Properties of Coal by the Constant-Torque Gieseler Plastometer"; 4) a plastic temperature range above about 50° C as determined by ASTM D2639; 5) a maximum fluidity of at least 300 ddpm (dial divisions per minute) and preferably greater than about 2000 ddpm as determined by ASTM D2639; 6) expansion greater than about 20% and preferably greater than about 100% as determined by Arnu Dilatation; 7) vitrinite reflectance in the range of from about 0.80 to about 0.95 as determined by ASTM D2798, "Test Method for Microscopical Determination of the Reflectance of Vitrinite in Polished Specimens of Coal"; 8) less than about 30 % inert maceral material such as semifusinite, micrinit, fusinite, and mineral matter as determined by ASTM D2798; and 9) no significant oxidation of the coal (0.0 vol% moderate or severe oxidation) as determined by ASTM D 2798 and non-maceral analysis. (The desirability of each of these individual properties and their order of preference will be further elaborated below.) The porous product or carbon foams thus produced, preferably as a net shape or near net shape, can be machined, adhered and otherwise fabricated to produce a wide variety of low cost, low density products, or used in its preformed shape as a filter, heat or electrical insulator etc. Such cellular products, with[out] further treatment and/or the addition of strengthening additives have been shown to exhibit compressive strengths of up to about 4000 psi. at densities of between about 0.3 and about 0.4 g/cm^3 or 19 to [19] <u>25</u> lb/ft^3. Other interesting properties of such

materials are tensile strengths of between about 300 and 1000 psi, shear strengths in the range of about 300 psi and impact resistances of between about 0.3 and 0.4 ft-lbs./in^2 as measured by Izod impact on a notched, 0.5 square inch cross-section sample. Impregnation with appropriate materials or the incorporation of various strength improving additives can further increase the compressive, tensile and other properties of these cellular materials. [Further treatment] Treatment by carbonization or graphitization yields cellular products that can be used as electrical or heat conductors.

Description of the Drawings

Figure 1 is a graph of showing the general relationship between gas evolution and time/temperature at various operating pressures and temperatures for the process of the present invention.

Figure 2 is a cross-sectional view of a "mold" containing powdered coal prior to expansion in accordance with the process of the present invention.

Figure 3 is a cross-sectional view of the "mold" of Figure 2 subsequent to expansion of the powdered coal in accordance with the process of the present invention.

Figure 4 is a cross-sectional diagram of an extruder suitable for the production of coal-based porous products in accordance with the present invention.

Detailed Description

According to the present invention, a preformed, low density, i.e., from about 0.1 to about 0.8 g/cm^3, preferably from about 0.2 to about 0.5g/cm^3 and most preferably from about 0.3 to about 0.4 g/cm^3, cellular product, carbon foam, is produced from powdered coal particulate preferably less than about ¼ inch in diameter by the controlled heating of the powdered coal in a "mold" under a non-oxidizing atmosphere. The starting material coal may include bitumen, anthracite, or even lignite, or blends of these coals that exhibit a "free swell index" as determined by ASTM D720 of between about 3.5 and about 5.0, but are preferably bituminous, agglomerating coals that have been comminuted to an appropriate particle size, preferably to a fine powder below about –60 to –80 mesh. Additionally, according to further highly preferred embodiments of the present invention the coal starting materials of the present invention possess all or at least some of the following characteristics: 1) a volatile matter content (dry, ash-free basis) of between about 35 and about [35%] <u>45%</u> as defined by ASTM D3175, "Test Method for Volatile Matter in the Analysis of Coal and Coke"; 2) a fixed carbon (dry basis) between about 50 and about 60% as defined by ASTM D3172, "Practice for Proximate Analysis of Coal and Coke"; 3) a Gieseler initial softening

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Abstract

According to the present invention there is provided a coal-based carbon foam having a density of between about 0.1g/ cm^3 and about 0.8 g/cm^3, preferably between about 0.2 g/cm^3 and about 0.6 g/cm^3 and most preferably between about 0.3 g/ cm^3 and about 0.4 g/cm^3 that is produced by the controlled heating of high volatile bituminous coal particulate in a "mold" and under a non-oxidizing atmosphere. The high volatile bituminous coal starting material preferably exhibits a free swell index of between about 3.5 and about 5.0 and most preferably between about 3.75 and about 4.5. A number of additional highly desirable characteristics of the high volatile bituminous coal starting material are also described. The carbon foam product thereby produced can be machined, adhered and otherwise fabricated to produce a wide variety of low cost, low density products, or used in its preformed shape as a filter, heat or electrical insulator etc. Such carbon foams, [without further] with treatment exhibit compressive strengths of up to about 6000 psi. Further treatment by carbonization or graphitization yields products that can be used as electrical or heat conductors. Methods for the production of these coal-based cellular products are also described.

It is therefore a object of the present invention to provide a relatively low cost, low density product that is suited to application in the construction, aerospace, transportation, metal processing and other industries where such properties are desired.

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2) a fixed carbon (dry basis) between about 50 and about 60% as defined by ASTM D3172, "Practice for Proximate Analysis of Coal and Coke"; 3) a Gieseler initial softening temperature of between about 380° C and about 400° C as determined by ASTM D2639, Test Method for Plastic Properties of Coal by the Constant-Torque Gieseler Plastometer"; 4) a plastic temperature range above about 50° C as determined by ASTM D2639; 5) a maximum fluidity of at least 300 ddpm (dial divisions per minute) and preferably greater than about 2000 ddpm as determined by ASTM D2639; 6) expansion greater than about 20% and preferably greater than about 100% as determined by Arnu Dilatation; 7) vitrinite reflectance in the range of from about 0.80 to about 0.95 as determined by ASTM D2798, "Test Method for Microscopical Determination of the Reflectance of Vitrinite in Polished Specimens of Coal"; 8) less than about 30 % inert maceral material such as semifusinite, micrinit, fusinite, and mineral matter as determined by ASTM D2798; and 9) no significant oxidation of the coal (0.0 vol% moderate or severe oxidation) as determined by ASTM D 2798 and non-maceral analysis. (The desirability of each of these individual properties and their order of preference will be further elaborated below.) The porous product or carbon foams thus produced, preferably as a net shape or near net shape, can be machined, adhered and otherwise fabricated to produce a wide variety of low cost, low density products, or used in its preformed shape as a filter, heat or electrical insulator etc. Such cellular products, with[out] further treatment and/or the addition of strengthening additives have been shown to exhibit compressive strengths of up to about 4000 psi. at densities of between about 0.3 and about 0.4 g/cm^3 or 19 to 25 lb/ft^3. Other interesting properties of such

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